NEW MILLENNIUM PROGRAM

Flight Validation of Technologies

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August 30, 1999

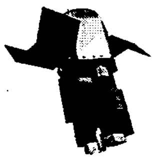
Ambitious Plans

Office of Earth Science

- EOS Post 2002

- LandSat Follow-on

- NPOES

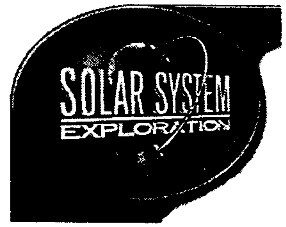


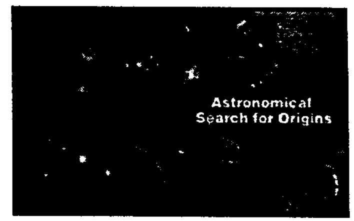
- Advanced Geostationary

- ESSP

Office of Space Sciences

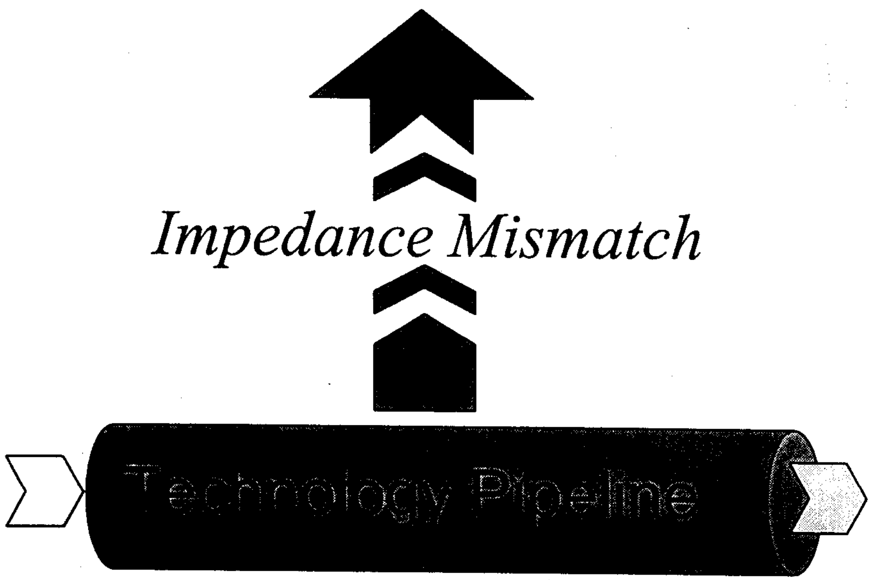
- Mars Exploration
- Outer Planets
- Discovery
- Solar Terrestrial Probes
- UNEX/SMEX/MIDEX
- Gravity Probe B/LISA
- Next Generation Space Telescope
- Space interferometry Mission/Terrestrial Planet Finder





Advanced Technologies:
Essential to Achieve OES and OSS Objectives

Science Missions

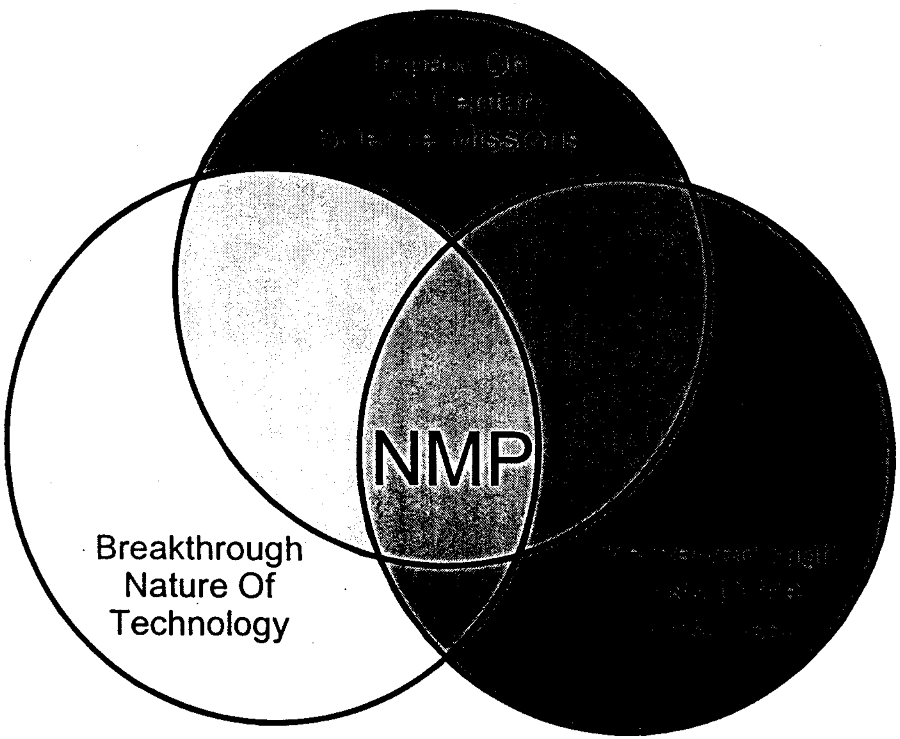


Impediments to Rapid Technology Infusion:

- Lack of flight heritage
  - real or perceived risks
    - cost
    - schedule
    - performance
- Little visibility to mission planners
  - capabilities poorly understood
  - A complete paradigm shift is needed to fully exploit some technologies

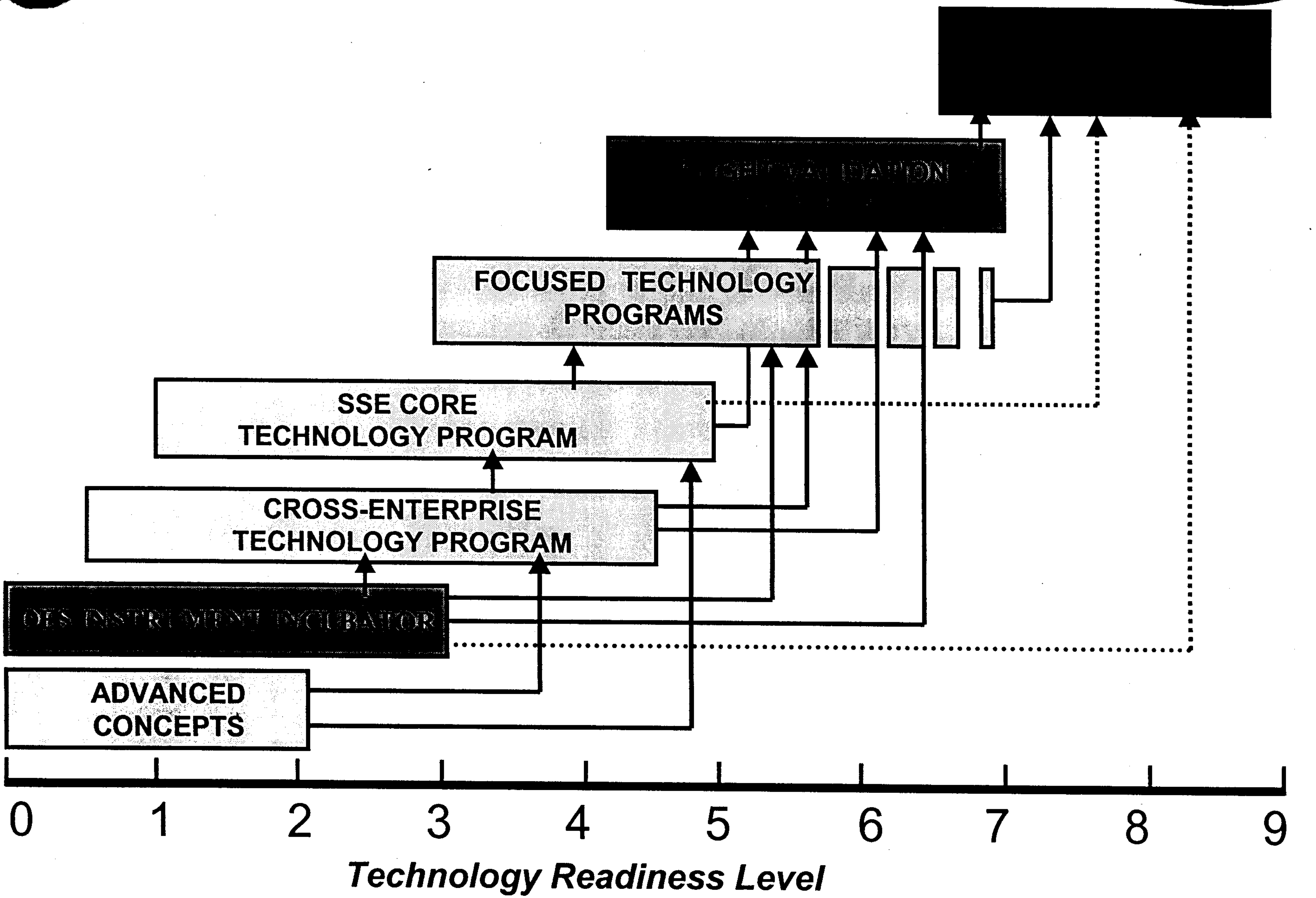
The New Millennium Program

A cross-Enterprise program to identify and flight validate breakthrough technologies that will significantly benefit future Space Science and Earth Science missions

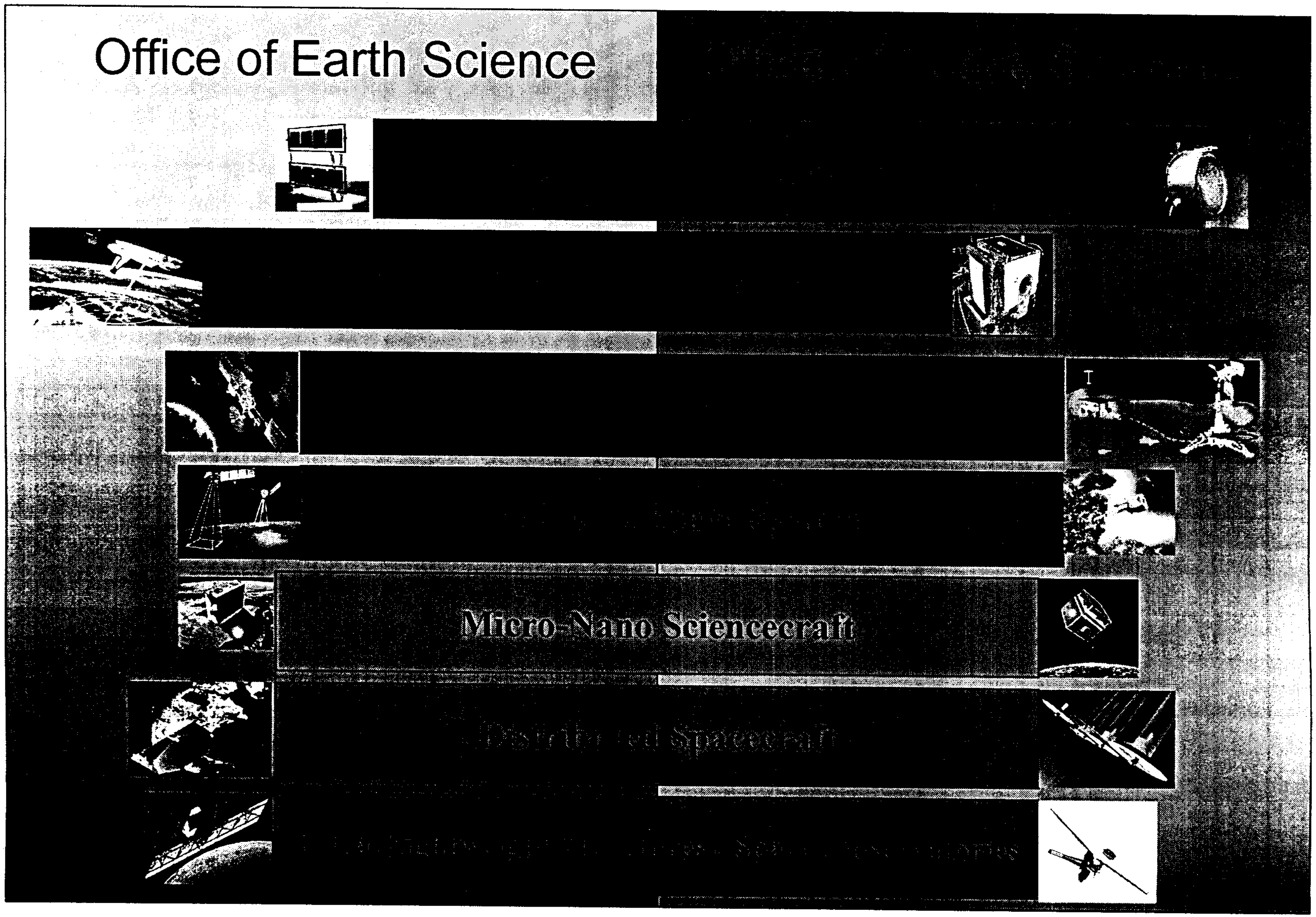


- Breakthrough technologies
  - Enable new capabilities to meet Earth and Space Science needs
  - Reduce costs of future missions
- Flight validation
  - mitigates risks to first users
  - enables rapid technology infusion into future missions

Technology Program Elements



Cross-Enterprise Technology Thrust Areas



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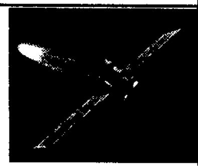
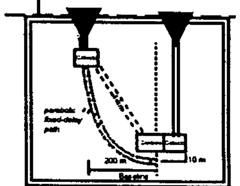
Validation Flight Launch Schedule

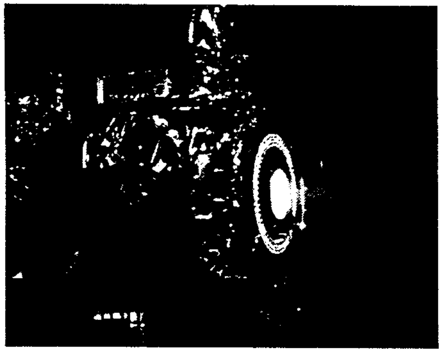
FY	98	99	00	01	02	03
DS1		▼ 10/98				
DS2		▼ 01/99				
EO1			▼ 12/99			
ST3						
ST5						▼ ▼
EO3						▼ ▼

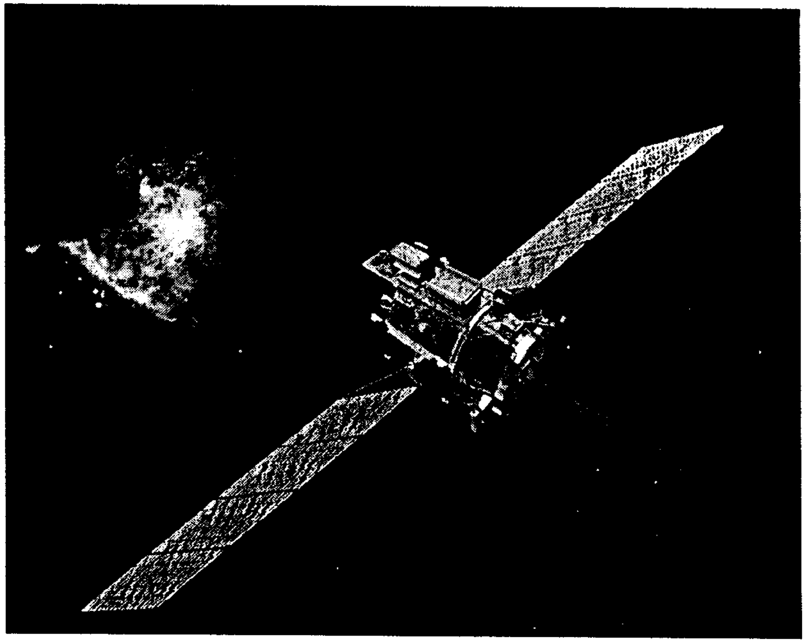
Deep Space 1
Rapid Access to Small Bodies

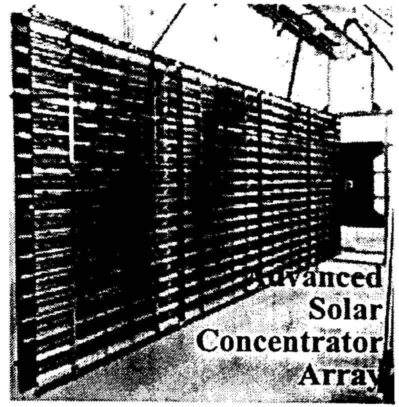
- Designed to validate ion propulsion and 11 other advanced technologies
- Successfully launched, October 24, 1998
- Technology Validation Status
  - all technologies fully validated
- Encountered Asteroid 1992KD on July 29, 1999
  - Significant science and technology return
- Extended mission will allow encounters with 2 comets in 2001:
  - Comet Wilson-Harrington
  - Comet Borelli

Deep Space 1

System Level Validation of 12 Breakthrough Technologies

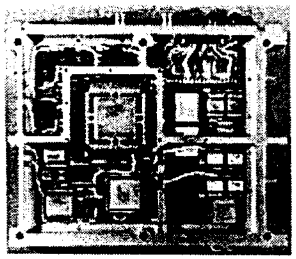




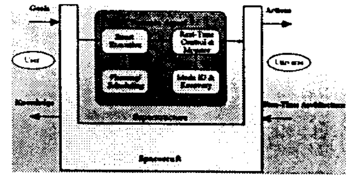


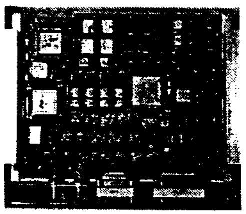
Advanced Solar Concentrator Array

Small Deep Space Transponder

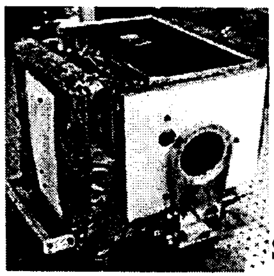


Remote Agent Architecture



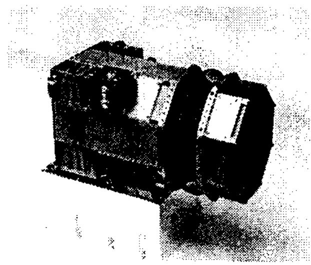


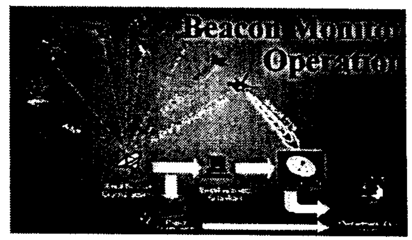
Low Power Electronics

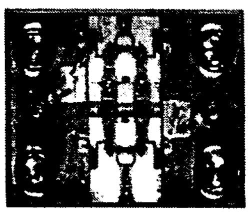


Miniature Integrated Camera Spectrometer

Plasma Experiment for Planetary Exploration

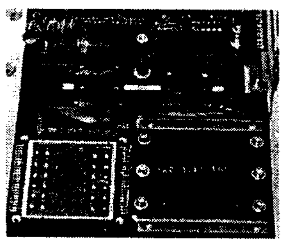




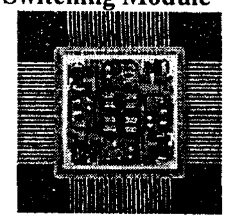


Ka-Band Solid State Power Amplifier

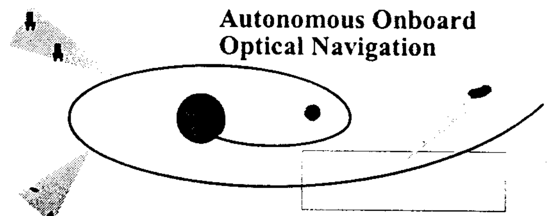
Multifunctional Structure



Power Activation & Switching Module



Autonomous Onboard Optical Navigation



Solar Electric Propulsion Future Users

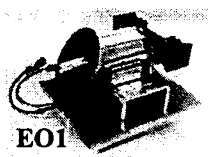
NMP

Advanced Solar Concentrator Array

EO-1 Lightweight flexible solar array

Light Weight Solar Arrays

NSTAR Ion Propulsion

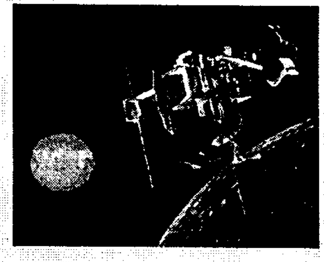


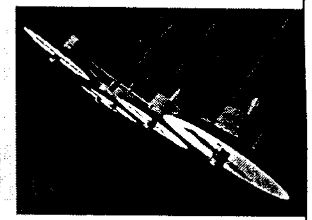
EO1

Pulsed Plasma Thruster

Electric Propulsion

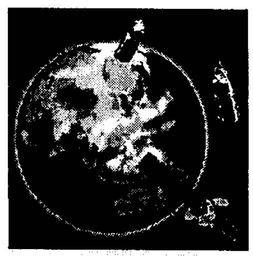
Space Science

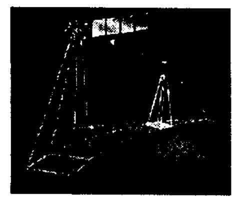


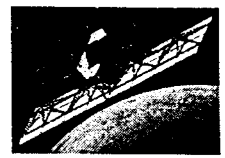


Benefits of Solar Electric Propulsion

- Transportation
- Formation Flying
- Station Keeping/Orbit Maintenance



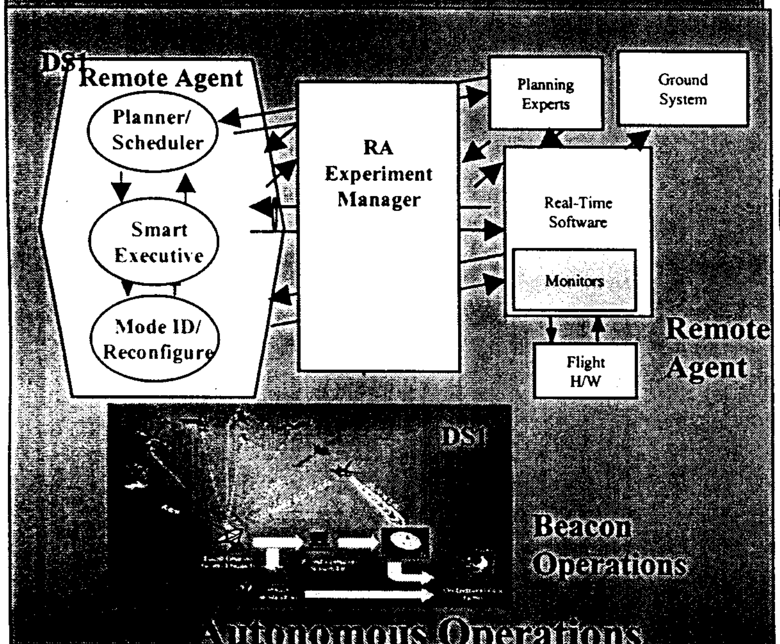




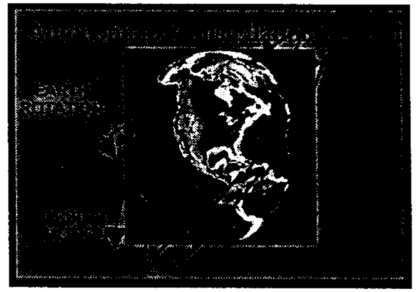
ESSP

Earth Science

Thinking Spacecraft Future Users



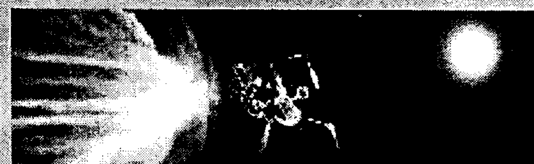
Earth Science

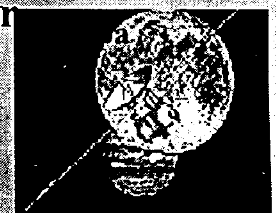


- Formation flying and/or autonomous operations for EOS and ESSP Missions

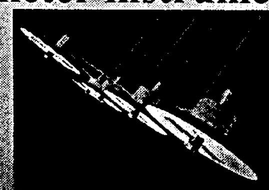
- Magnetospheric Multiscale, Magnetospheric Constellation
- Self monitoring for Europa Orbiter, MIDEX proposals & Earth orbiters

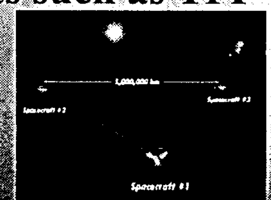
- Autonomous optical navigation for Stardust, and Europa Orbiter





- Automatic sequencing & real time control for interferometer instruments such as TPF and LISA





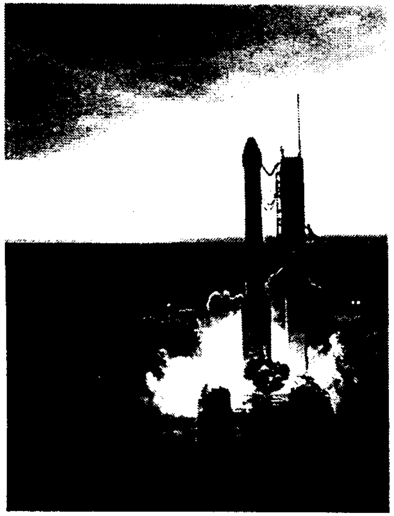
Space Science

Deep Space 2: Mars Microprobes

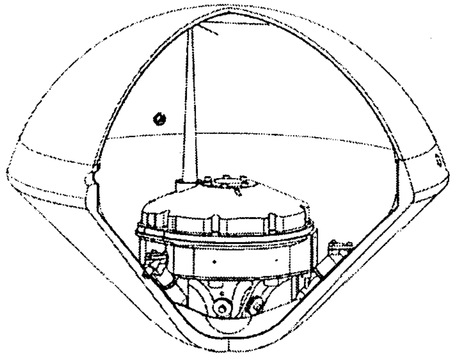
- Designed to validate technologies for surface penetrators and network science
  - Passive entry, descent, and landing system
    - built to survive high-g impact (30,000 - 80,000 g's)
  - Miniaturized Electronics
    - power, microprocessor, telecom
  - Low-temperature batteries
  - Soil acquisition/Water detection experiment
- 2 probes successfully launched, January 3, 1999
  - Piggyback on Mars Surveyor 98 Lander cruise stage
- Landing in Martian South polar regions
  - December 3, 1999
  - Validation data expected after landing

Deep Space 2

Technologies for surface penetrators and network science

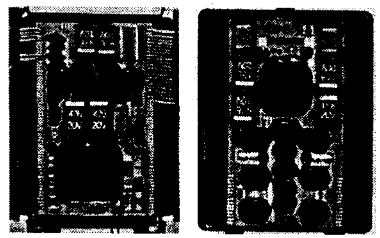


Launch:
January 3, 1999



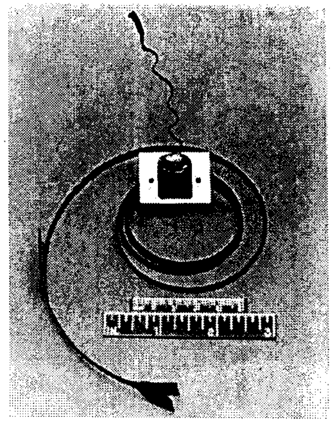
Single-Stage, Passive Aeroshell Entry System

Power Microelectronics

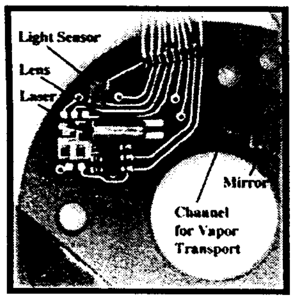


Probe Entry
December 3, 1999

Flexible Interconnect

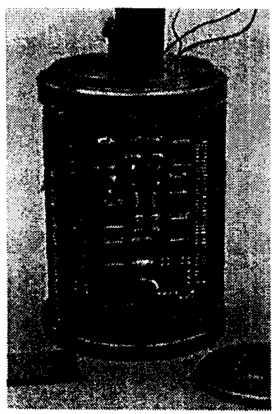


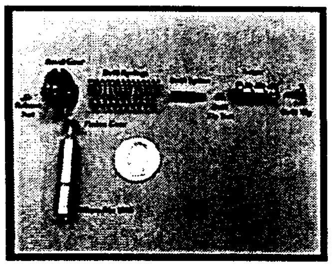
Landed Operations:
Primary Mission: 2 Sols (extended mission battery dependent)



Miniaturized Tunable Diode Laser Spectrometer
Subsurface Water Detection

Advanced Microcontroller

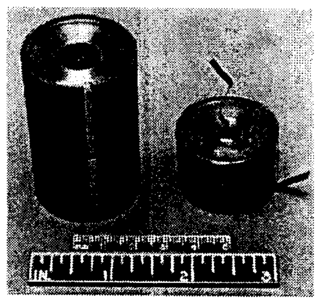


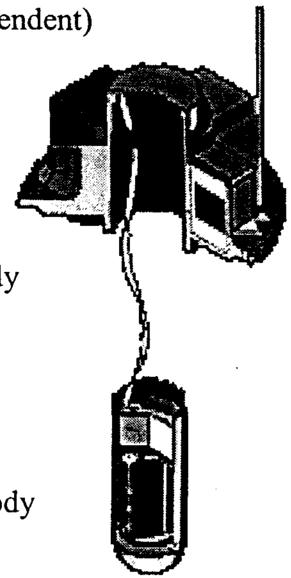


Motor / Drill Assembly

Drill and Soil Acquisition System

Lithium Ion Batteries

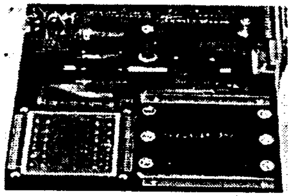




Aftbody

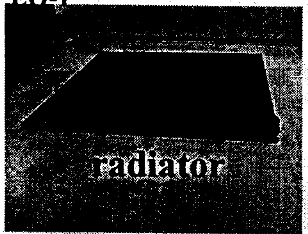
Forebody

Micro-Nano Spacecraft's Future Users



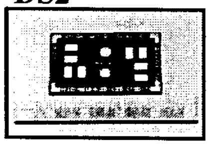
Multifunctional structure

EO-1



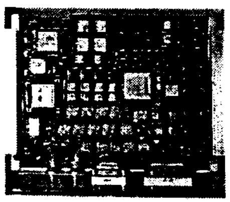
DS1

DS2



Advanced Micro Controller

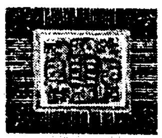
DS1



Low Power Electronics

Small Deep Space Transponder

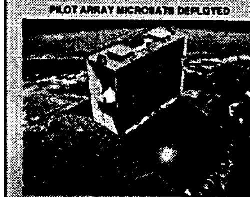
DS1

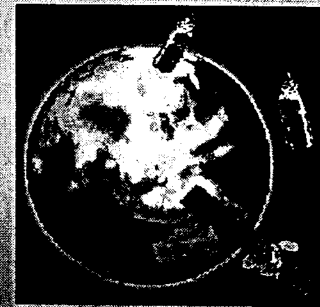


Power switching module

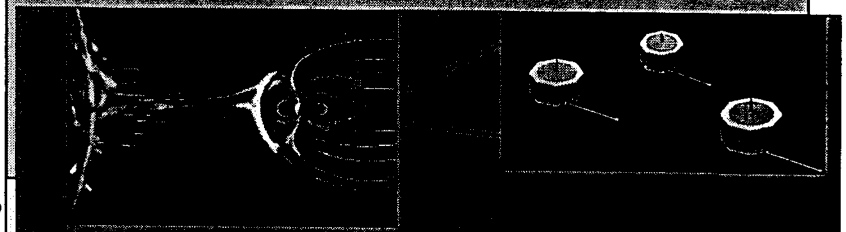
Innovations that simplify design, fabrication, reduces mass & reduce resource requirements

Earth Science

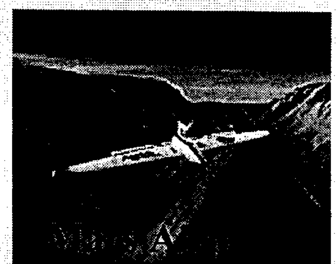




- Potential for EOS Follow-On
- ESSP and Earth Probes



- STP Magnetospheric Multiscale Mission



DISCOVERY

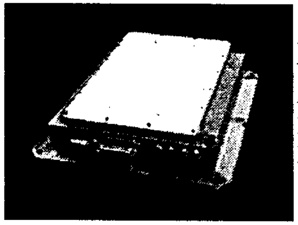
SMEX

- Mars Micro missions
- Discovery
- UNEX/SMEX/MIDEX

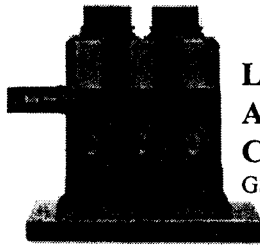
Space Science

Earth Observer 1

Validation of 9 Breakthrough Technologies

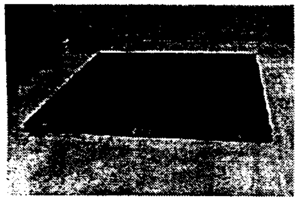


X-Band Phased Array Antenna:
Boeing, GSFC & Lewis Research Center

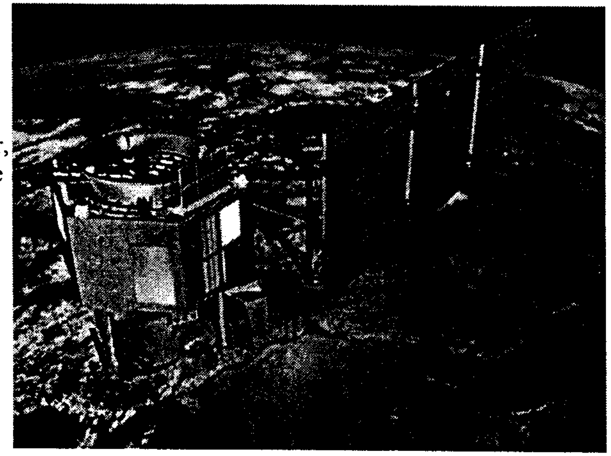


Leisa Atmospheric Corrector:
GSFC

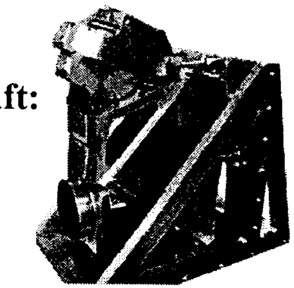
Advanced Land Imager:
MIT Lincoln Lab, GSFC, Raytheon / Santa Barbara Remote Sensing, & Sensor Systems Group



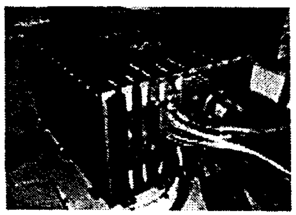
Carbon-Carbon Radiator:
Air Force Research Lab, Amoco Polymers, BF Goodrich, GSFC, Langley Research Center, Lockheed Martin, Naval Surface Warfare Center, & TRW



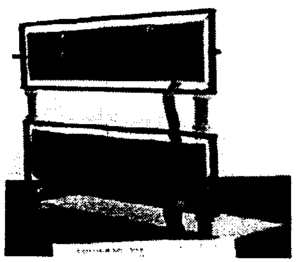
Spacecraft:
GSFC, Litton, SWALES



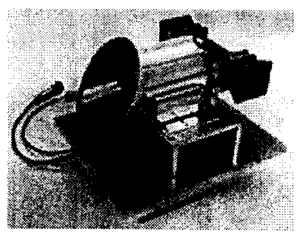
Hyperion:
TRW, JPL, GSFC



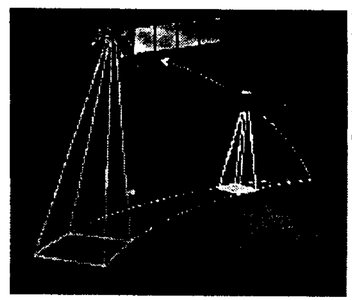
Wideband Advanced Recorder Processor:
GSFC, Litton, MIT Lincoln Lab, Swales, & TRW



Lightweight Flexible Solar Array:
GSFC, Lockheed Martin, & Phillips Lab

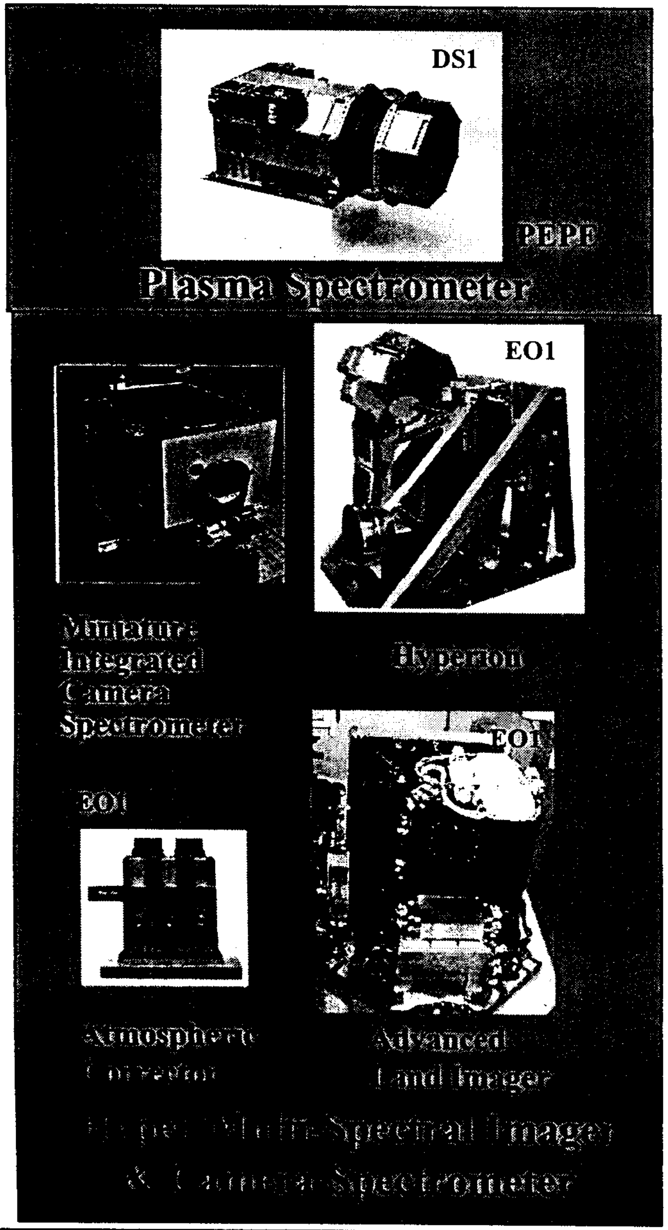


Pulsed Plasma Thruster:
GSFC, Lewis Research Center & PRIMEX

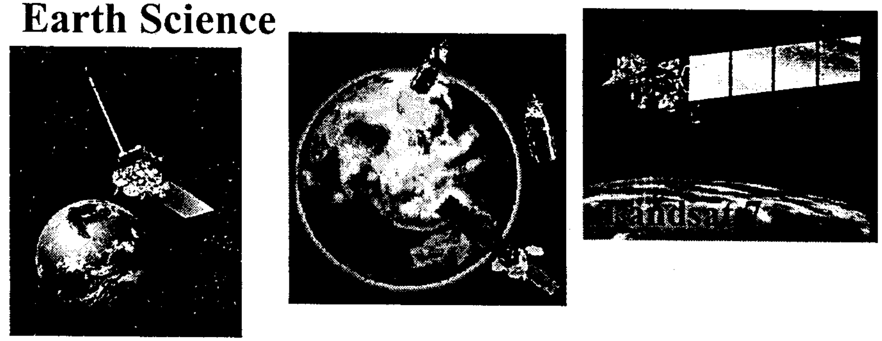


Enhanced Formation Flying
GSFC, JPL

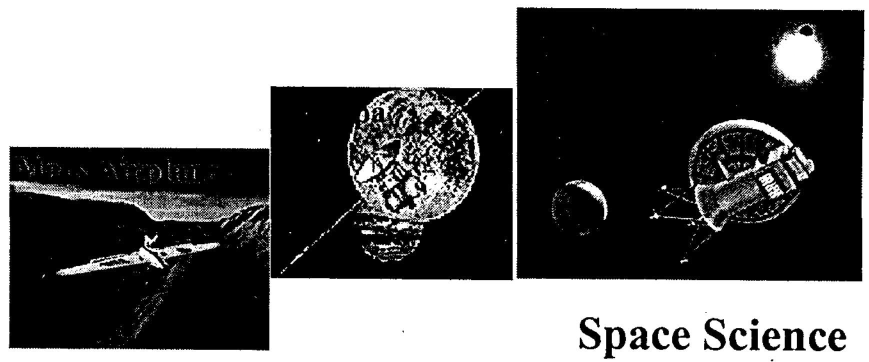
Hyper/Multi-Spectral Imagers & Spectrometers Future Users



Earth Science



- Planetary & solar plasma scientists have proposed to use copies of the PEPE instrument for future missions
- Validation of an all SiC optical instrument covering the FUV to SWIR will enable many new miniature, low-mass cameras and spectrometers



Space Science

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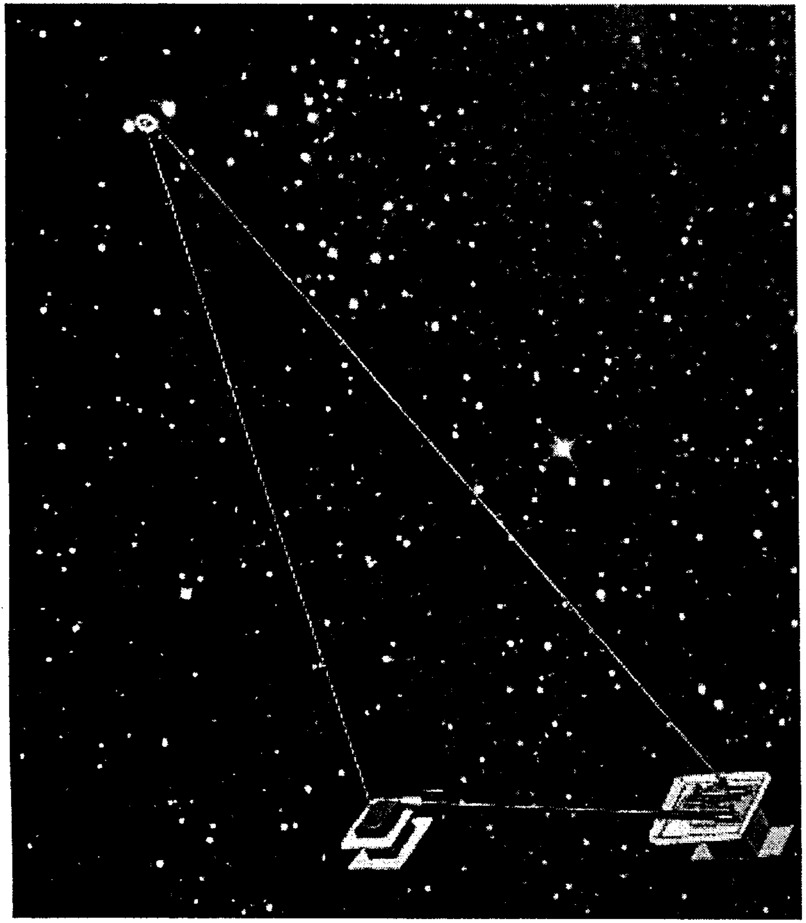
ST3: Two Spacecraft Interferometer



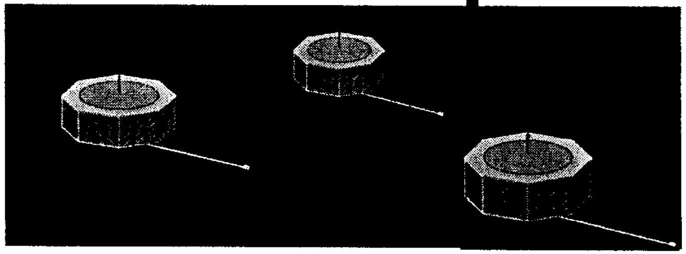
- S/C separation from 50 m to 1 km
  - Observation baselines of 40 to 200 m
  - 8th magnitude stellar targets
- Parabola is locus of constant delay
- Combiner contains 20 m fixed delay line
- Combiner can operate as a 1 m monolithic interferometer
  - No collector, bypass fixed delay
- Both S/C maintain fixed orientation relative to each other during baseline changes

NMP_ESS_OSS_GSFC.ppt

The ST5 Opportunity

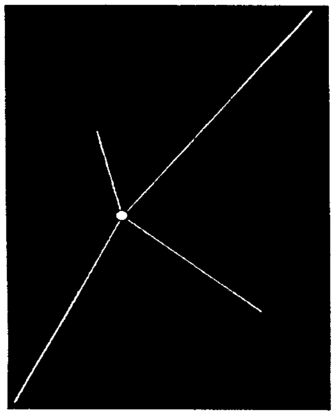
- ST5 will validate technologies for
  - Structure and Evolution of the Universe (SEU)
  - Sun-Earth Connection (SEC)
- Current technology themes
  - Disturbance reduction system technologies (e.g. LISA)
  - Solar sail (e.g., sun polar orbiter, interstellar probe, etc)
  - Nanosatellite (e.g., magnetospheric constellation, etc.)
- Technology RFP issued, March 1999
  - Successful proposers incorporated into study teams
  - Each team prepares a report for mission selection review
- ST5 is a low-cost validation flight
  - Total implementation phase budget of <$30M

ST5 Concepts



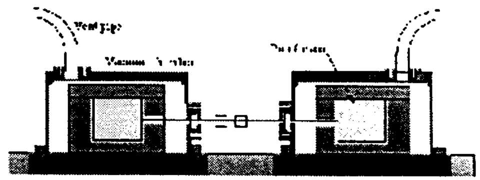
Nanosatellites

– Small (spinning) spacecraft, deployed and operated in constellations
– Each with multiple small Fields and Particles Instrument Technologies



Solar Sail

– Propulsion system to place spacecraft in desired locations unreachable (or un-maintainable) by alternative propulsion systems
– Small Fields and Particles Instrument Technologies (on bus, sail or sub-sat.)



Disturbance Reduction System

– Inertial and position sensing technologies for precision spacecraft positioning - for future gravitational and interferometric applications

The EO3 Opportunity

The NASA OES directed the NMP to:

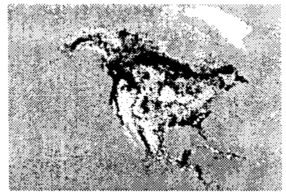
- Focus the third Earth Observing mission, EO3, on innovative measurement concepts for remote sensing observations from orbits beyond conventional low-Earth orbit (LEO)
  - Geostationary orbits
  - Highly elliptical orbits
  - Mid-Earth and high-Earth orbits
  - L1 and L2
- Issued a NASA Research Announcement (NRA) to solicit the measurement concepts
  - Maximize participation by the Earth science and technology communities
  - identify revolutionary technologies, and/or measurement strategies
- 24 proposals were submitted and peer reviewed by the OES
- 4 concepts were selected for a 6-month study
  - downselected to one or two flight projects before 9/30/99

EO3 Measurement Concepts

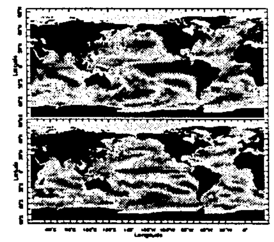
Four Measurement Concepts were chosen for further study as candidates for EO-3 mission

Geostationary Imaging Fourier Transform Spectrometer
Dr. William L. Smith, LaRC

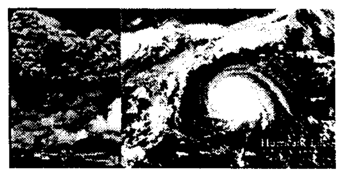
Active Large Aperture Optical Systems for High Resolution Thermal Imaging from Geosynchronous Orbit
Del Jenstrom, GSFC



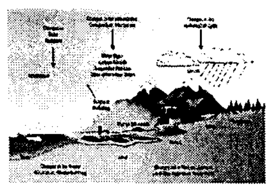
Land-Cover and Land-Use Change



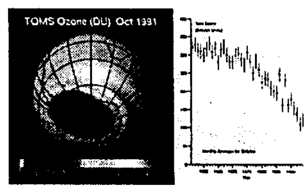
Seasonal-to-Interannual Climate Variability and Prediction



Natural Hazards Research and Applications



Long-Term Climate: Natural Variability and Change Research



Atmospheric Ozone Research

Technology-focused NMP Process

- Alignment with Science theme need insured by
  - selecting technologies to address specific capability needs in science roadmaps
  - involvement of science community in identification, review and where appropriate, validation of technologies
- Phase A Concept Definition is technology focused
  - Open, peer-reviewed competition for technologies
  - For system validation, science AO in Phase B where appropriate
  - Provide capabilities needed to enable future high-priority science missions
  - Provide significant improvements in performance, or reductions in life-cycle cost
  - Require validation to mitigate risks to first science user
  - selected technologists participate in project concept definition team
- Independent review of project concepts prior to selection

Key Participants in NMP Process

Science Community

- Defines capability needs in theme roadmaps
- Participates with NMP to identify technology requirements, review technology candidates / concept studies, and participates via AO where appropriate

NASA HQ

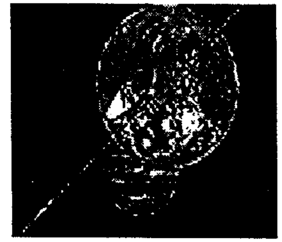
- Defines priorities and constraints for Projects
- Authorizes project concept definition studies
- Leads peer reviews of technology solicitation
- Assigns project implementation center
- Conducts independent reviews
- Selects and approves project for implementation
- Where appropriate, selects science support via AO

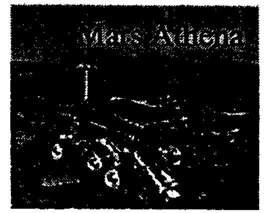
NMP

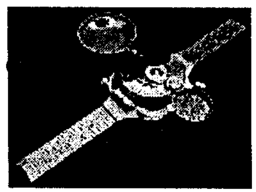
- Leads identification of technology validation candidates
- Conducts project concept definition studies
- Selects technology providers through open competition
- Oversees project implementation

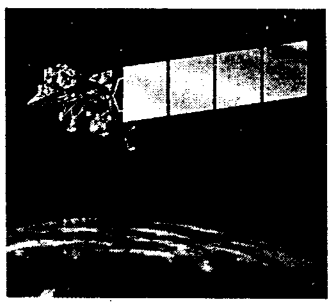
Benefits of NMP Processes

- Enhanced NASA's technology community through partnerships
  - Industry
  - Academia
  - Government Laboratories
- Infusion into future missions
  - Future projects using NMP validated technologies
  - Technology database for PI missions
    - New capabilities enable new opportunities
    - MIDEX/SMEX/Discovery/ESSP









PILOT ARRAY MICROSATS DEPLOYED

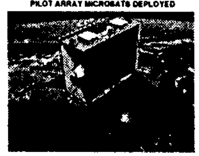
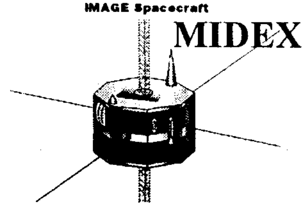


IMAGE Spacecraft



SMEX

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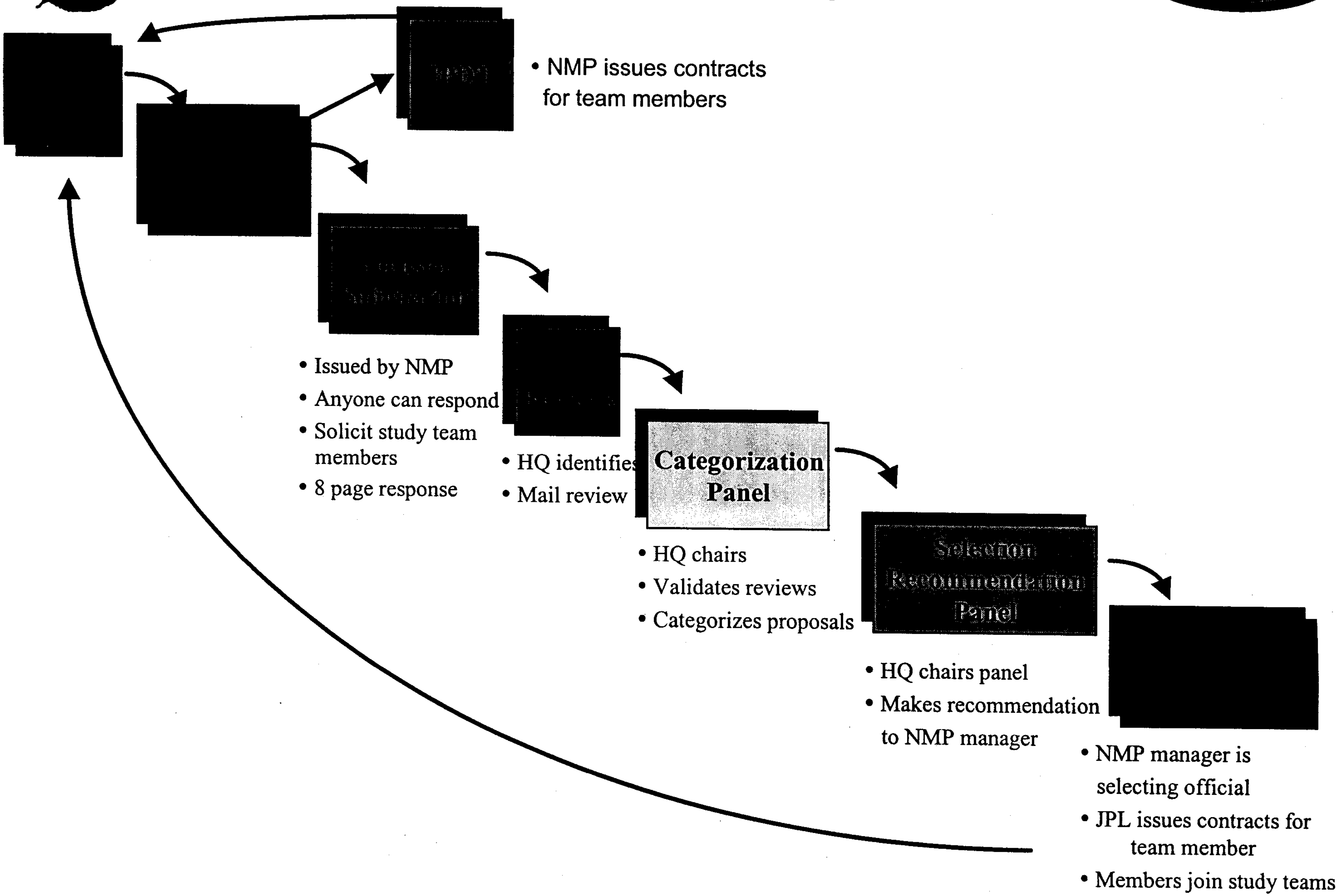
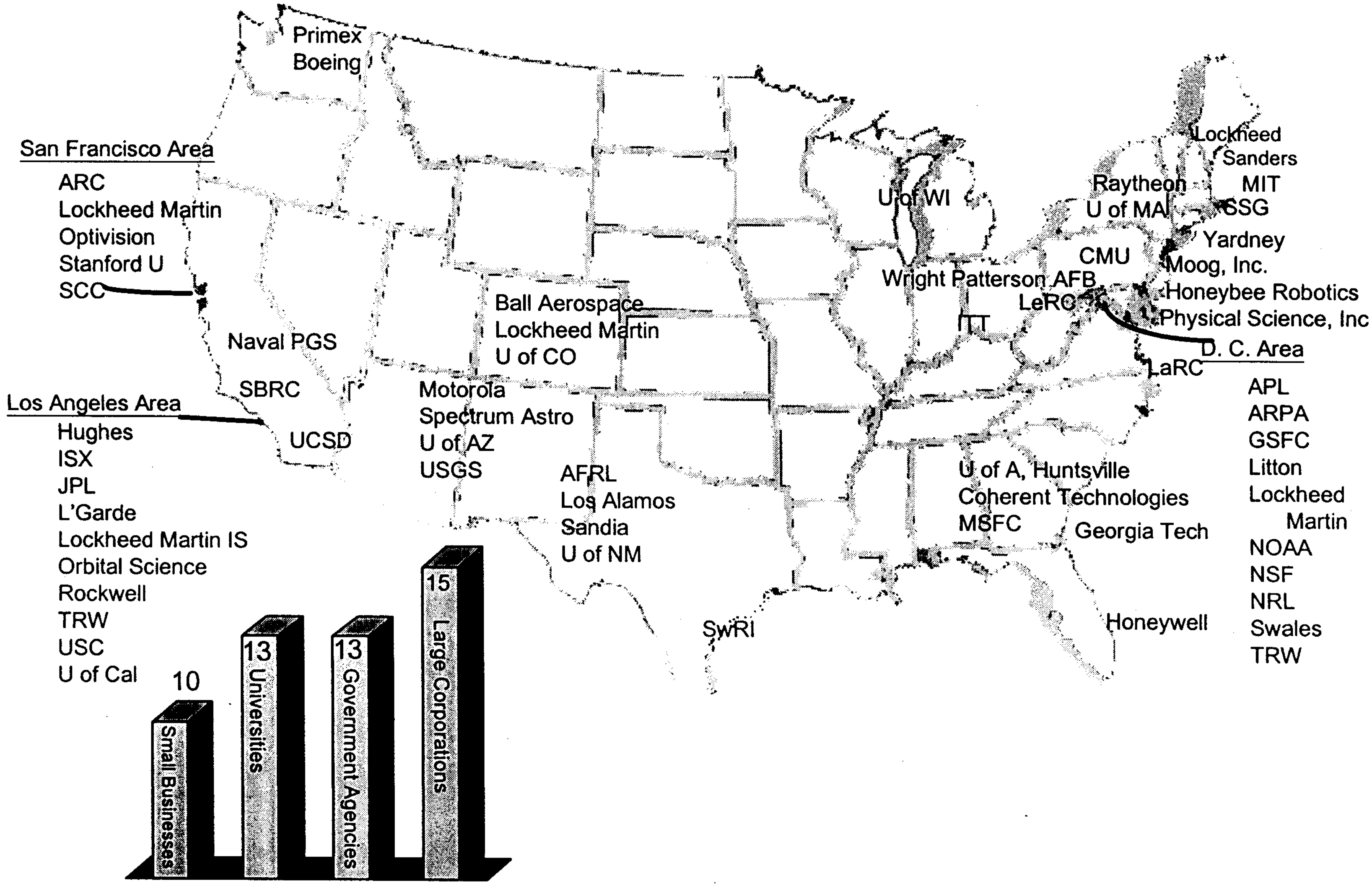
Example: EO3 Technology Solicitation



Enhanced NASA Technology Community through Partnerships
(NMP Flight Team & Technology Partners)



EO3 Technology Selection Attributes

- Rapid selection process
  - Only one call for all teams
- Solicit study team members
  - Must present best available technology
- Peer review process
  - NASA HQ manages reviews
  - Study leads recommend one member to participate
- Selection and contract administration by NMP
  - Relieves centers and study teams of burden
- Selection results in pre-qualified flight article supplier
  - Saves time, no follow-on solicitation

Technology database for PI missions - Advanced Land Imager

New capabilities enable new opportunities MIDEX/SMEX/Discovery/ESSP

Technology Readiness Database for Discovery 1998

System or Subsystem (from Level 2 WBS) Advanced Land Imager	**POC Name/Org:** Nick Speciale **POC Phone:** (301)286-8704 **POC E-mail:** speciale@pop500.gsfc.nasa.gov
Technology Name and Supporting UPN or other funding source NMP EO-1 UPN: 246	**URL for Additional Information:** http://eo1.gsfc.nasa.gov/

Description of Technology:
The Advanced Land Imager (ALI) is the centerpiece of the New Millenium, Earth Orbiter-1 mission and will validate technologies contributing to the reduction in cost of future land imaging missions such as the Landsat series or earth imaging missions. The ALI will provide multi-spectral (10 bands), high spatial resolution (30km) in the visible and near infrared spectral range (.5 to 2.5 um) with the goal of 5% absolute radiometric accuracy. The EO-1 mission will fly in formation with Landsat 7 and collect more than 200 common scenes for comparison.
The ALI will be a factor of 4 less in mass and 5 less in power than the Landsat 7 Enhanced Thematic Mapper (ETM+). The flight validation of key ALI technologies should lead to dramatically reduced cost and complex Landsat type missions. Some of the key technologies are:

1> Silicon Carbide Optics which are extremely lightweight optics that are stable over a wide range of temperatures. The goal is to demonstrate how well the Silicon Carbide maintain stable performance in a space environment.

2> Wide field, high resolution reflective optics which provides a full Landsat scene swath width (185km) and resolution using a simple push broom design. This technique will enable much lower cost instrumentation for future Landsat mission through use of non-mechanical scanning and reduced instrument complexity.

3> Multi-spectral imaging capability, the modular focal plane assembly provides substantial mass and power savings over comparable mechanical scanning instruments through innovative electro-optical design. Additionally, an innovative on-board calibration system will enable better characterization of instrument performance during observations.

Applicability
The ALI is a pathfinder to higher performance and lower cost land imaging instruments which meet the demanding Earth Science Enterprises requirements for remote sensing applications.

Benefit to Earth Science Missions
The ALI technologies reducing the mass, power, complexity and cost of future earth imaging systems for the Earth Science Program. A fully operational ALI has potential for reducing the cost and size of future Landsat type instruments by a factor of four to five.

Development Status and Plans for Flight Readiness

Technology Maturity	Description	Date (to be) Completed
Component and/or breadboard validation in relevant environment		
System/subsystem model or prototype demonstration in a relevant environment (ground or space)	The flight ALI is currently undergoing integration at Lincoln Labs. The flight telescope has been delivered and the flight focal plane will be delivered in the mid- June timeframe. Calibration will occur in the Aug to November 1998 timeframe	Dec 1998
System prototype demonstration in a space environment	The ALI will be launched on the EO-1	May 1999
Actual system completed and "flight qualified" through test and demonstration (ground or space)	The ALI technologies will be fully flight qualified after it has completed one year of operation in the space environment	May 2001
Actual system "flight proven" through successful mission operations	ALI science objectives will be fully met after ALI completes land imaging for an entire growing season	Sept 2001

Technology database for PI missions - NSTAR Electric Propulsion

NMP

New capabilities enable new opportunities MIDEX/SMEX/Discovery/ESSP

Technology Readiness Database for Discovery 1998

System or Subsystem (from Level 2 WBS) Spacecraft Propulsion System	**POC Name/Org:** J. F. Stocky **POC Phone:** (818) 354-5358 **POC E-mail:** john.f.stocky@jpl.nasa.gov
Technology Name and Supporting UPN or other funding source NSTAR Solar Electric Propulsion UPNs: 242, 632, 839	**URL for Additional Information:**

Description of Technology:
NSTAR is a high-specific-impulse solar electric propulsion system for deep space primary propulsion. The NSTAR system consists of five principal elements:

1. A 30-cm ion thruster capable of processing 83 kg at power levels between 500 W and 2,500 W and providing 93 milli-N of thrust and an I_{sp} of 3,120 lb_f-sec/lb_m at maximum power.
2. A power processing unit (PPU) capable of providing the necessary voltages and currents required by the ion thruster from an input power source providing between 80 V and 160 V. Each power processing unit can control two ion thrusters sequentially, but not simultaneously.
3. A digital control interface unit (DCIU) that provides the command and telemetry interface with the spacecraft, which controls the power processing unit - establishing proper set points for each throttle level commanded by the spacecraft, and which controls the flow rates provided by the propellant storage and control system.
4. A propellant storage and control system (PSCS) that provides Xenon to the ion engine at the flow rates commanded by the DCIU for each throttle level.
5. A diagnostics measurement system to measure induced fields during ion thruster operation to help verify the performance of the ion propulsion system and to measure the effect of its operation on the space plasma near the spacecraft. The diagnostics system is not required for operational use of the ion propulsion system.

Applicability
The NSTAR engine is applicable to many deep space missions, and particularly valuable for missions to distant or high delta-v targets.

Benefit to Deep Space Missions
NSTAR provides significantly higher specific impulse than conventional chemical propulsion. This translates into a smaller mass of fuel required to accelerate a spacecraft to a given velocity. On missions to distant objects or trajectories requiring a large delta-v, where the fuel mass is a significant factor, a smaller fuel load at launch can mean a smaller, lower cost launch vehicle, or it can be traded for higher spacecraft velocity or a shorter cruise time to the target for a given launch vehicle capacity.

Development Status and Plans for Flight Readiness

Technology Maturity	Description	Date (to be) Completed
Component and/or breadboard validation in relevant environment		
System/subsystem model or prototype demonstration in a relevant environment (ground or space)	An engineering model ion thruster, functionally identical to the flight ion thruster, was tested for 8,000 hours at full power. The flight ion thruster, PPU, and DCIU have been protoflight qualified.	Completed
System prototype demonstration in a space environment		
Actual system completed and "flight qualified" through test and demonstration (ground or space)	The flight ion thruster, PPU, DCIU, and Xenon feed system have been environmentally and functionally qualified to protoflight levels prior to use on DS1. A long-duration test with flight hardware processing 125 lb_m of Xenon and using the full throttle range of the system	Completed Dec. 2000
Actual system "flight proven" through successful mission operations	Complete mission profile as primary propulsion system for DS1	Dec. 2000